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TARGET DETECTION USING BLACK-AND-WHITE TELEVISION
STUDY I: THE EFFECTS OF RESOLUTION DEGRADATION ON TARGET DETECTION

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ABSTRACT

The probability of detecting an M-48 tank at four different levels of television (TV) resolution (800, 600, 400, and 300 lines) was investigated on a black-and-white closed-circuit TV system.

The four levels of TV resolution were presented to 16 subjects, who were asked to indicate in which one of nine areas the tank appeared on the TV screen.

The data indicated that subjects performed about equally well at the 800, 600, and 400 levels of resolution; however, their performance was significantly poorer at the 300 level of resolution. The tank's location on the TV screen was an important factor in the probability of target detection, but was confounded with other variables.

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TARGET DETECTION USING BLACK-AND-WHITE TELEVISION STUDY I: THE EFFECTS OF RESOLUTION DEGRADATION ON TARGET DETECTION

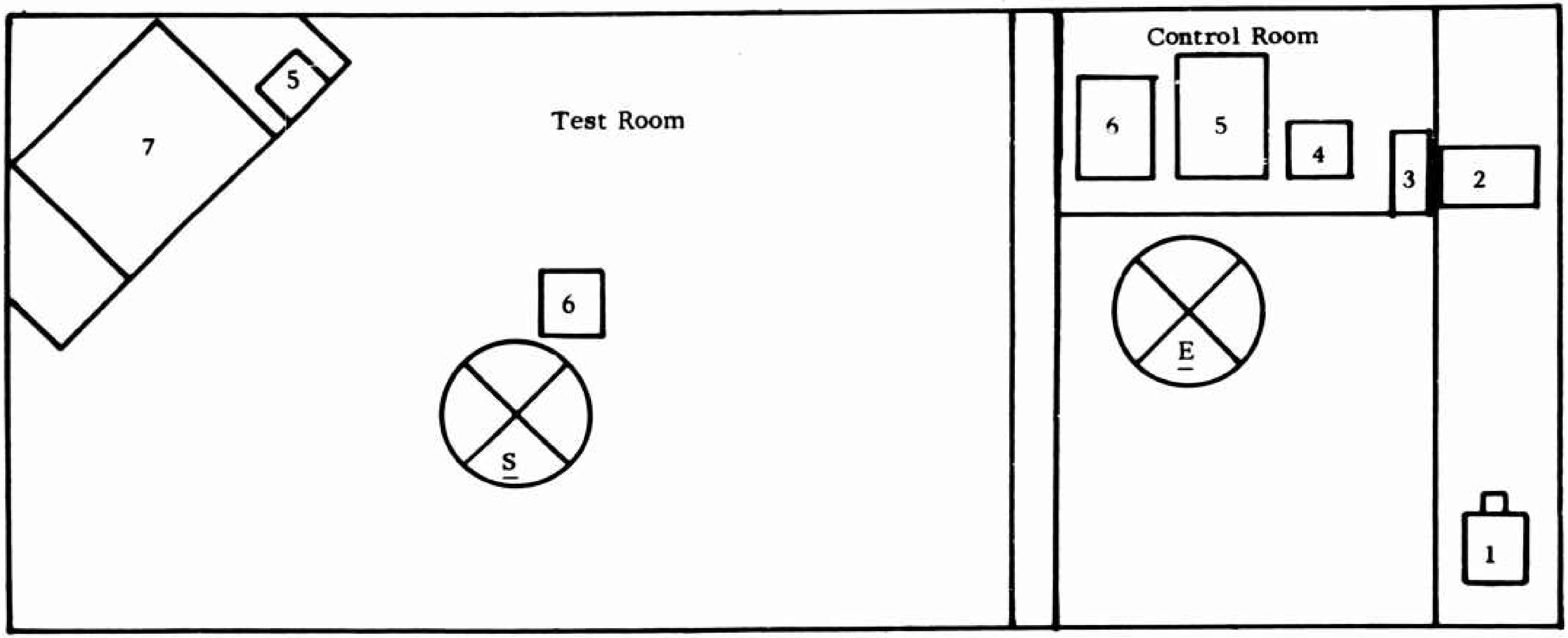
INTRODUCTION

Television (TV) is becoming an important means of presenting visual information to man in a variety of military applications. Television is currently being used for many different military purposes. For example, TV has been used to present visual information to operators of remote-control combat vehicles (5). In another study (6), men have driven tanks using a TV display as the sole source of visual information. Television has also been used in lunar and planetary explorations and in satellites that provide televised reconnaissance information. In military control centers (2), TV displays are used for more effective weapon system deployment and damage assessment. The increasing use of TV in modern weapon and surveillance systems makes more stringent demands on the operators' ability to accurately interpret TV displays.

In some military applications of TV, the operator's task would be to detect and identify targets on the TV display. In a recent article, Gordon (4) has pointed out that target detection and target identification are two important aspects of the combat situation. Target detection ordinarily refers to an observer's ability to determine whether a man-made object is present or absent in a place where such objects are not usually seen. Target identification, on the other hand, refers to the observer's ability to characterize or specify the object he has detected.

Little attention has been given to the extent to which TV resolution affects the probability of target detection. In a preliminary study, Oatman (7) compared target-location scores from a projected-slide display and a TV display. Performance was superior with the slide display, which was interpreted as due to better resolution. Freeberg (3) found that reducing information on a video screen increased form thresholds significantly. In a more recent study, Shanahan (8) found that reducing the bandwidth of a closed-circuit TV system likewise reduced the subjects' ability to identify targets.

The present study attempted to measure the effects of resolution on the probability of detecting targets on a black-and-white closed-circuit TV system.



1. TV Camera
2. Foto-Video F-101A TV Light Box
3. Hunter Interval Timer
4. Standard Timer
5. Intercom
6. Response Panel
7. 14-inch TV Monitor

Fig. 1. ARRANGEMENT OF EXPERIMENTAL TEST AND CONTROL ROOMS

METHOD

Subjects

Sixteen male enlisted men from the U. S. Army served as subjects (Ss). The Ss' ages ranged from 18 to 26. The Ss' vision (corrected or uncorrected) ranged from 20/20 to 20/13 as measured by Ortho-Rater tests.

Apparatus

Television

The equipment for the TV presentation was a General Precision Laboratories P.D.-601 closed-circuit high-resolution TV system. The TV camera in a control room fed radio-frequency (RF) signals to a 14-inch TV monitor in an adjacent test room. A Foto-Video F-101A light box, holding one 8" by 10" positive-transparency photograph, was placed in front of the TV camera.

The TV monitor in the test room was divided into nine equal areas by black thread. The Ss had a response panel with nine buttons, which was similarly divided into nine areas by thin strips of masking tape. Each button on the response panel represented one of the areas on the TV monitor. The control room contained a similar panel to display the Ss' responses.

The amount of time that a picture remained on the TV monitor was controlled by a Hunter interval timer, model 100-C, series D. A Standard electric timer recorded the Ss' response times. There was an intercom to provide communication between the test and control rooms. Figure 1 shows the experimental arrangements.

Picture Degradation

Freeberg (3) pointed out that bandwidth can be linearly related to the number of scan lines per frame. However, in this experiment, the number of scan lines per frame in the actual displayed TV picture remained at 875 lines. The picture was degraded by an appropriate reduction in bandwidth which, in turn, reduced the information in a horizontal scan line. Thus the amount of information within a scan line was decreased, but there was reduction only in the horizontal dimension. To obtain four levels of picture degradation (800, 600, 400, and 300, as measured with a standard RETMA TV test pattern), four different values of capacitance to ground were inserted into the coaxial cable between TV camera and monitor. The capacitance to ground, in conjunction with other elements in the TV circuit, acted as a low-pass filter. The bandwidth was reduced to 20.0, 6.0, 1.7, and 1 megacycles, which correspond to the 800, 600, 400, and 300 levels of resolution respectively. The amount of picture degradation (800, 600, 400, and 300) was measured with a standard RETMA TV test pattern, and these levels refer to resolution in the center of the TV screen.

Procedure

After S was checked for visual acuity, he was seated approximately 72 inches from the TV screen, instructed, and given the response panel. Each S saw ten 8" x 10" photographs, nine showing an M-48 tank (one in each area) against a homogeneous background, and one showing only the background. The tank was 3/8" long and 3/16" wide, subtending a visual angle of 18 minutes.

Every S saw the ten photographs four times, at each of the four levels of picture degradation. The photographs were shown in a random order, identical for all Ss.

To offset practice effects, the four levels of resolution were presented in the same order (800, 600, 400, and 300) to all Ss, but each S began with the level following the one at which the preceding S began. For example, the first S observed the photographs at the 800, 600, 400, and 300 levels of resolution; the next S observed them at the 600, 400, 300, and 800 levels; the third began with the 400 level; and so on, until all Ss had observed the photographs at all levels. Since the Ss were initially selected at random, assigning them to groups by this procedure gave random groups.

The TV monitor was always illuminated. When the experimenter started the interval timer, the picture was transmitted from the control room to the Ss' monitor in the test room for a 0.5-second exposure.

If the S saw no target on the screen (and there was none when the blank slide was presented), he pushed any two buttons.

RESULTS

Two aspects of the Ss' performance were measured: response times and detections. Response time was defined as the time between the target's appearance on the TV screen and the S's response. A detection error occurred when S could not locate the target on the TV screen. In scoring, one point was allowed for each correct detection.

A constant value of one was added to all treatment-by-subject cells in order to avoid blank cells in the analysis. This procedure raised the means by one but did not affect the variance.

Tables 1 and 2 present the means and standard deviations for the correct detection scores and response times, as a function of picture degradation. These means were analyzed with Duncan's (1) multiple-range test for correlated means. Detection scores on the 300-level-resolution TV display differed significantly ($p < .01$) from those on the 400-, 600-, and 800-level-resolution TV displays. However, the 400-, 600-, and 800-level-resolution TV displays did not differ significantly on detection scores. With response time, none of the resolutions differed significantly from the others.

TABLE 1

Means and Standard Deviations of Correct Detection Scores as a Function of Resolution (N = 144/cell)

	Resolution			
	800	600	400	300
Mean	3.41	3.25	3.23	2.78
Standard Deviation	0.83	0.96	1.02	1.14

TABLE 2

Means and Standard Deviations of Response Times
as a Function of Resolution
(N = 144/cell)

	Resolution			
	800	600	400	300
Mean	1.55	1.55	1.53	1.83
Standard Deviation	0.51	0.76	0.47	0.78

Tables 3 and 4 give summaries of the analyses of variance of detection scores and response times. With correct detection scores, the main variables of resolution and locations were significant ($p < .01$). However, the locations variable was the only significant main effect ($p < .01$) for response times. All of the interactions were significant ($p < .01$) for the response times; but only two interactions, resolution by subjects and locations by subjects, were significant ($p < .01$) for the detection scores.

TABLE 3

Summary of Analysis of Variance of Correct Detection Scores

Source	df	Sum of Squares	Mean Square	F
Resolutions (A)	3	31.07	10.36	6.11**
Locations (B)	8	63.36	7.92	11.98**
Subjects (C)	15	194.69	12.98	--
A x B	24	13.04	0.54	1.23
A x C	45	76.23	1.69	3.84**
B x C	120	79.36	0.66	1.50**
A x B x C	360	158.91	0.44	--
Total	575	616.66		

** $p < .01$

TABLE 4

Summary of Analysis of Variance of Response Times

Source	df	Sum of Squares	Mean Square	F
Resolutions (A)	3	10.31	3.43	2.43
Locations (B)	8	7.12	0.89	6.04**
Subjects (C)	15	49.59	3.30	--
A x B	24	6.47	0.26	5.67**
A x C	45	63.55	1.41	29.73**
B x C	120	17.66	0.14	3.09**
A x B x C	360	17.10	0.04	--
Total	575	171.80		

** $p < .01$

DISCUSSION

The results show that reducing the bandwidth reduces target-detection probability significantly. Although it was expected that reductions in bandwidth and/or resolution would affect the probability of target detection, it is interesting that the relationship between resolution and target detection probability is nonlinear. The data indicate a significant difference between 300 and 400; however, there were no significant differences between the 400, 600, and 800 levels of resolution. One factor which may influence the obtained relationship is the fact that the resolution was reduced only in the horizontal plane. It seems likely that the Ss' equivalent performance on the 400, 600, and 800 levels of resolution may be attributed to the unchanged vertical resolution (650). However, the Ss' performance decreased at the lowest horizontal resolution level (300).

The interaction of resolution by subjects was significant for both detection scores and response times. These interactions are plotted in Figures 2 and 3, both of which show only two levels (800 and 300) of resolution. The figures show that Ss perform quite differently at different levels of resolution.

With response time, there was a significant interaction between resolution and location. The plot of this interaction, in Figure 4, indicates that mean response time differs as a function of resolution and location; however, for the most part, mean response time is faster with higher levels of resolution.

The analysis of variance indicated that the target location on the TV screen significantly affected the number of correct detections. The percentage of correct detections for each of the nine areas on the TV screen is plotted in Figure 5. The highest percentages of correct detections were in the upper middle, middle, and lower middle areas of the TV screen. Percentage of correct detections was lowest in the corners of the TV screen. However, the effects of the target's location on the TV screen are confounded by several other factors. First, Ss use different techniques to scan visual displays, so the obtained location effects could occur if the middle areas of the TV screen are scanned more frequently than other areas. However, this scanning effect is confounded with a second factor: resolution. With a bandwidth of 20 megacycles, resolution is not uniform across the surface of the TV monitor. When the center of the screen has 800-line resolution, the level in the corner areas may be as low as 500. Conceivably, this accentuated degradation in the TV display's corners could account for low target-detection probabilities in the corners. A third factor which is confounded with the location effect is the luminance of the TV screen. The TV screen's luminance, as measured with a Pritchard photometer (model 1970-PR), is not uniform. When the center area of the screen measures 7.6 foot-Lamberts, the corner areas may be as low as 6.2 foot-Lamberts. It is possible, therefore, that these differing luminance values may also contribute to low target-detection probabilities in the corner areas.

SUMMARY

This experiment investigated how TV resolution affects target-detection probability. Sixteen Ss viewed an M-48 tank on a closed-circuit black-and-white TV system under four levels of resolution (800, 600, 400, and 300). The Ss' task was indicating in which one of nine areas the tank appeared.

The data indicate that Ss' target-detection probability decreases significantly between the 300 and 400 levels of resolution; however, there were no significant differences among the 400, 600, and 800 levels of resolution. In addition, the target's location on the TV screen affected the target-detection probability significantly; however, this effect was confounded with resolution, luminance, and Ss' search techniques.

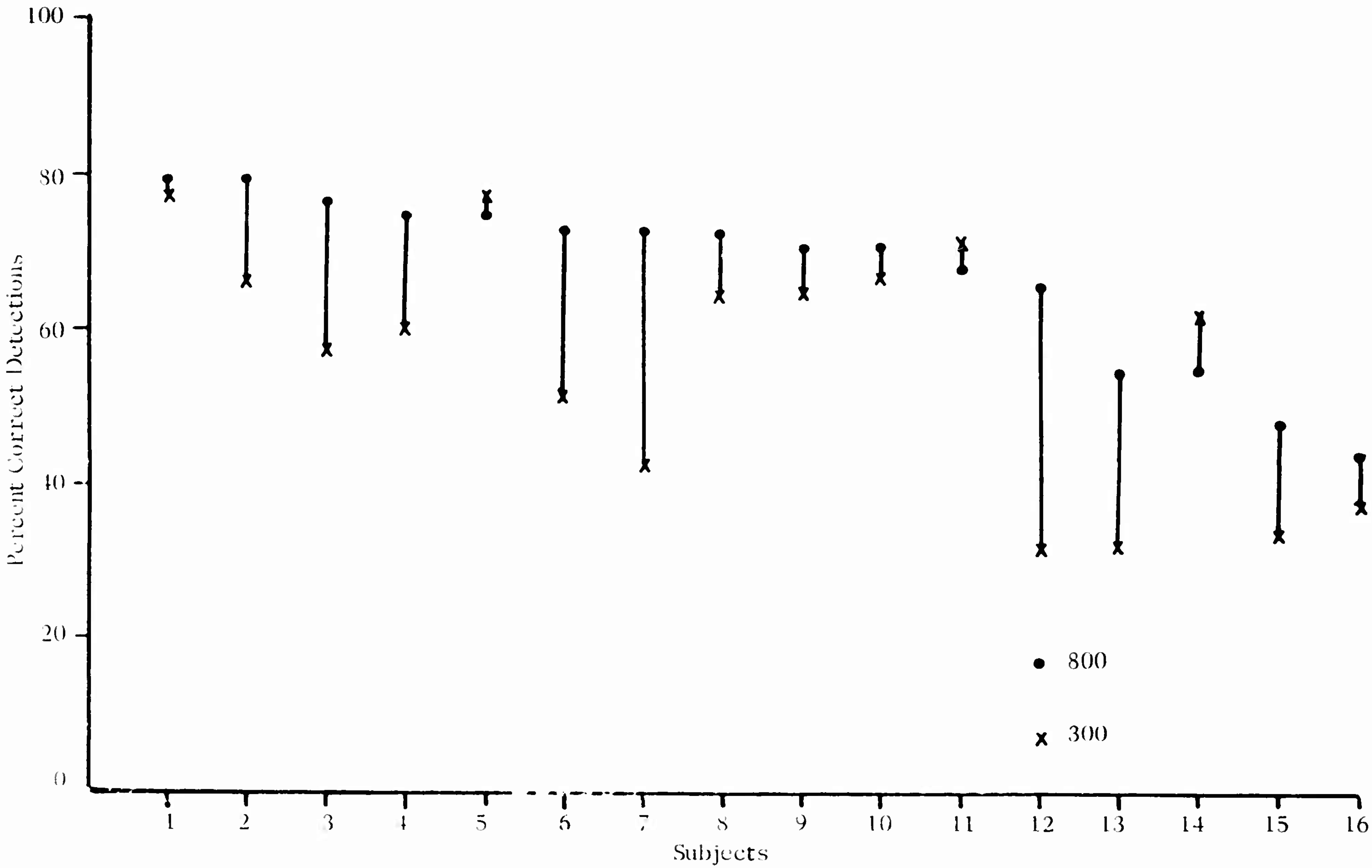


Fig. 2. PERCENT CORRECT DETECTIONS AS A FUNCTION OF RESOLUTION AND SUBJECTS

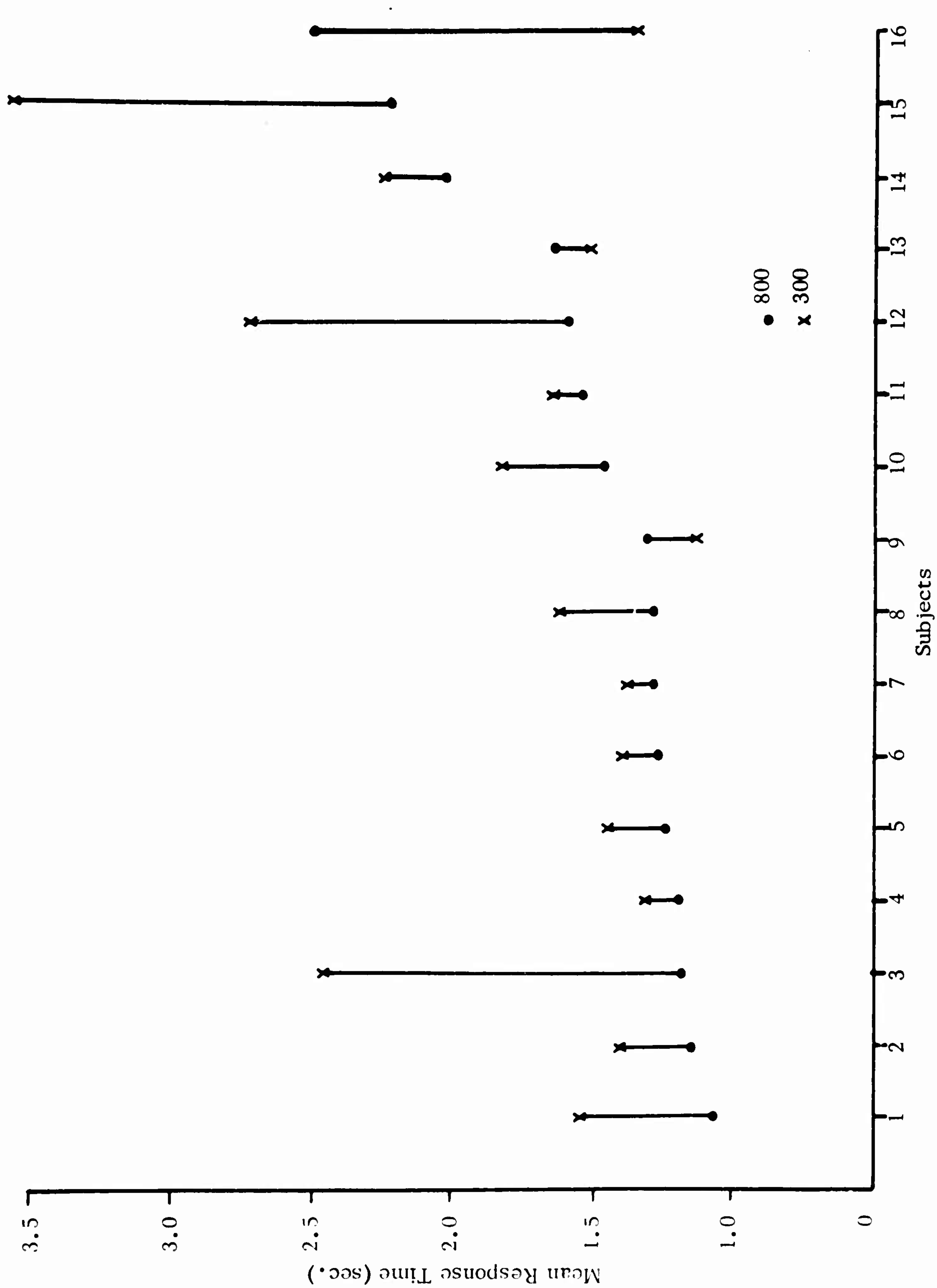


Fig. 3. MEAN RESPONSE TIME AS A FUNCTION OF RESOLUTION AND SUBJECTS

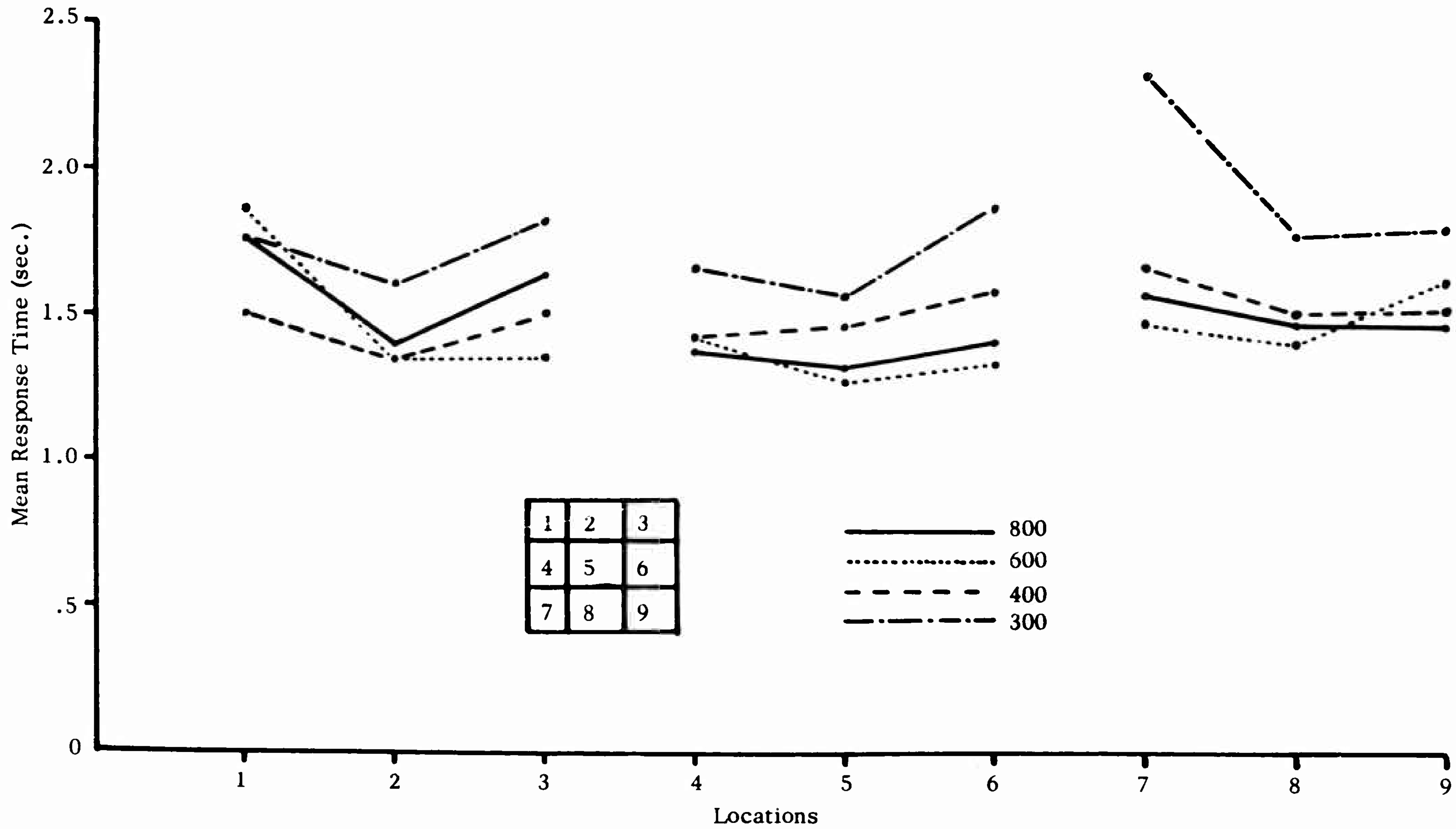


Fig. 4. MEAN RESPONSE TIME AS A FUNCTION OF RESOLUTION AND LOCATIONS

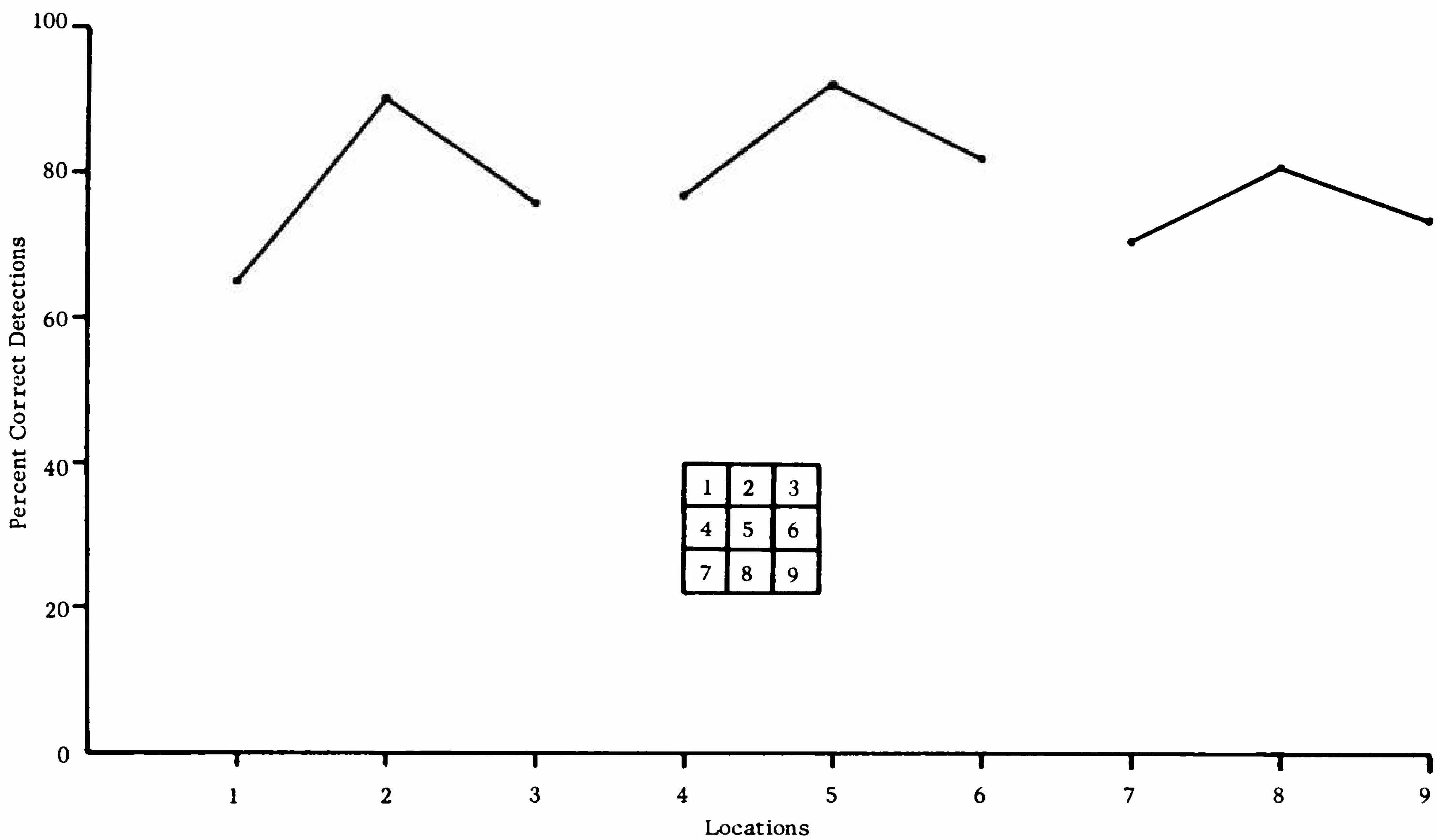


Fig. 5. PERCENT CORRECT DETECTIONS AS A FUNCTION OF LOCATIONS

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APPENDIX

INSTRUCTIONS TO SUBJECTS

We are going to present a series of pictures on the screen. Each one will be a photograph in which there may be a military target (tank), or the screen may be blank. Here is an example (SLIDE ONE). Can you spot the target? As you see, it is in the ______ grid on the screen. This panel is also marked into nine areas. As soon as you spot the target, press the button that corresponds with the area on the screen where you see the target. Press the button as soon as possible after you spot the target. If the screen does not have a target, push two different buttons (any two). I will say "Ready" before I flash each slide. If the TV fails at any time, notify me through the intercom. Do you have any questions?

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